Integrated Communication Navigation and Surveillance (ICNS) Conference

Communication Requirements and Architectures for Flight Information Services

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Presenter: Sunita Munjal

Rob Nichols – robert.nichols@jhuapl.edu
Rob Pattay – robert.pattay@jhuapl.edu
Sunita Munjal - sunita.munjal@jhuapl.edu
Communication Systems and Network Engineering Group
Power Projection Systems Department
JHU Applied Physics Laboratory, Laurel, MD

Outline

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  - LOS Architectures and Scores
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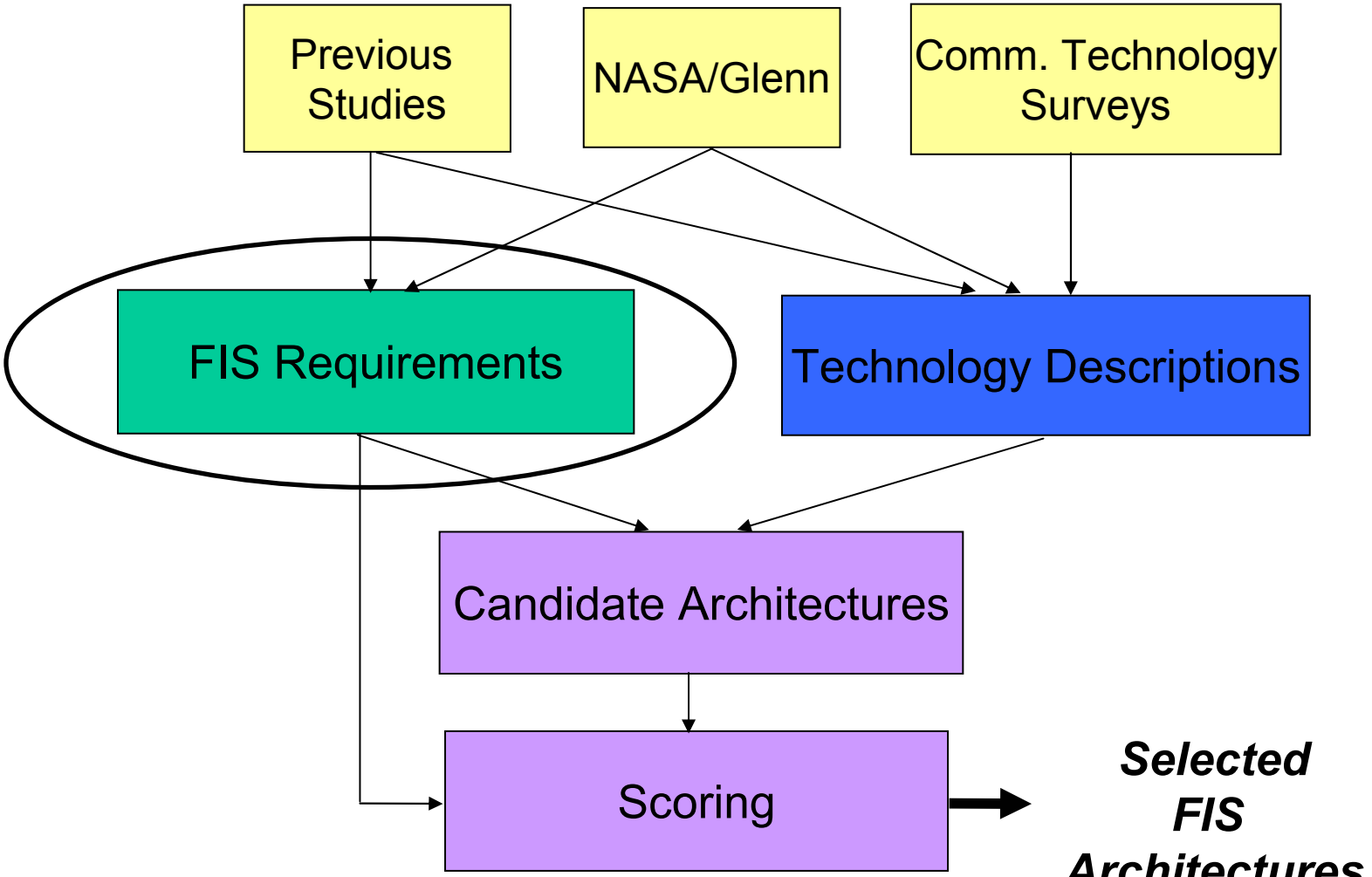
  - Alternative Architectures
- Summary

Project Background

- APL is sponsored by the NASA Glenn Research Center (GRC) in the Weather Information Communications (WINCOMM) element of the Aviation Safety Program (AvSP)
  - Communications architecture development
  - Modeling/simulation (M&S)
- Architecture work is focused on two aviation applications:
  - Flight Information Services (FIS)
  - Tropospheric Airborne Meteorological Data Reporting (TAMDAR)
- M&S work focused on Automated Dependent Surveillance -Broadcast (ADS-B) links

Architecture Analysis Process



FIS Requirements

- Requirements were examined across the following areas:
  - Latency
  - Capacity
  - Connectivity/Topology
  - Number of Elements
  - Platform Constraints
  - Coverage
  - Link Availability
  - Cost
  - Traffic Type
  - Protection
  - Spectrum
- Various sources were used to derive estimates

Capacity Analysis

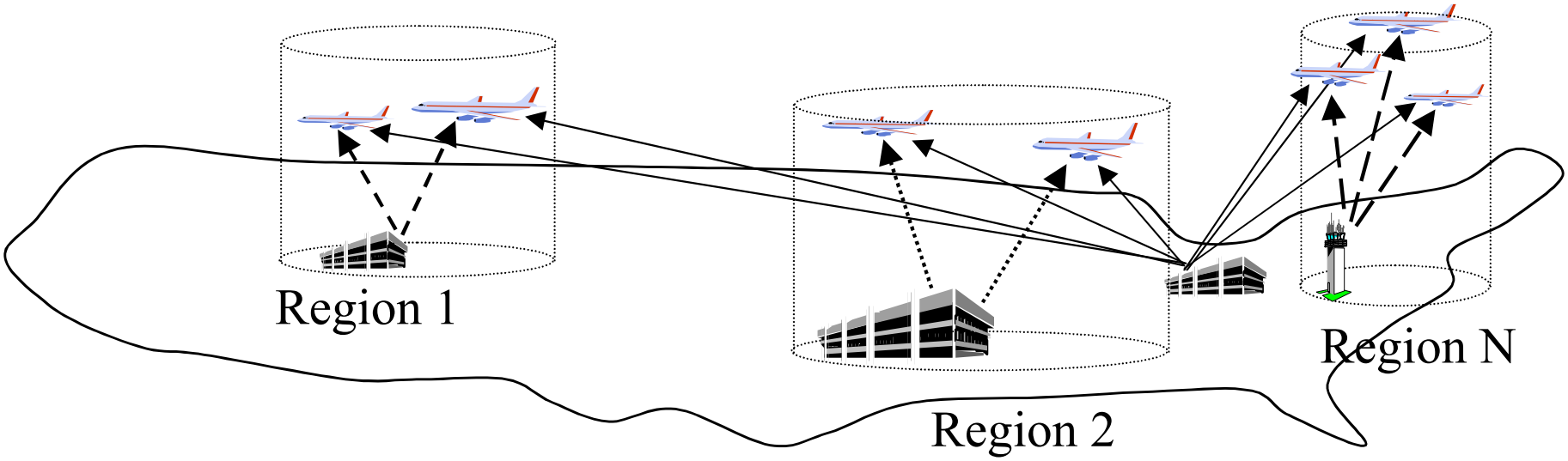
- Capacity is a function of required product types, sizes and latency
  - Primarily weather products
  - "NAS Status" also included as part of FIS (e.g., NOTAMs)
- Assumptions/limitations of capacity estimate:
  - Snapshot-in-time analysis
    - Attempted to obtain conservative product instances (e.g., images with weather activity)
  - Off-the-shelf lossless compression used (determining optimal approach beyond current scope)
  - Derived capacity from other posited FIS requirements (5-minute latency, 20% overhead)
- *Should be viewed as first-order estimate, not as conclusive requirement*

Distribution Approaches

High Fidelity Comprehensive Distribution (HFCD)

vs.

Multi-Fidelity Comprehensive Distribution (MFCD)



FIS distribution must consider the need for products with regional and CONUS perspectives

Text Product Capacity

- Products
  - METARs, TAFs, PIREPs, AIRMETs/SIGMETs, NOTAMs
  - E.g., METAR "KBWI 241354Z 07008KT 10SM CLR 11/M01 A3031 RMK AO2 SLP264 T01111006"
- Compression
  - BZIP2, GZIP, Stuffit, Compress, ZIP
  - Ratios up to 6.5:1
- Regional load based on approximate LOS communications area

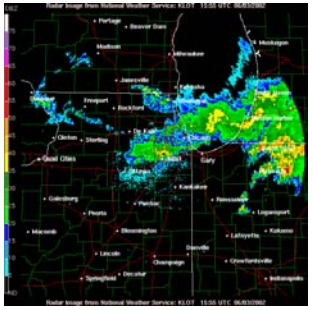
Product	CONUS [bps]	Max. Regional [bps]
METAR	748.8	26.3
TAF	444.8	15.6
PIREP	294.4	15.4
AIRMET/SIGMET	83.2	35.3
NOTAMS	1545.6	232.8
Total	*3116.8*	*325.4*

Graphical Product Capacity

- Products
  - Clouds, Turbulence, Icing, Wind/Temp., Surface Conditions, Convection, Satellite, NEXRAD, Lightning
- Compression
  - PNG
  - Ratios up to 20:1
  - Some much lower (e.g., satellite)
- Regional load based on approximate LOS communications area

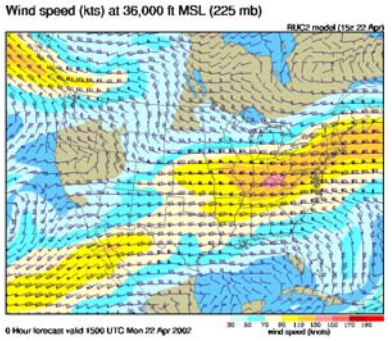
Examples (CONUS and Regional)

Convection



NEXRAD

Turbulence



Wind

Graphical Product Capacity

CONUS

Product	Size (bytes)	Full Set: No. of prod. types	Full Set: Cap. (bps)	Reduced Set 1: No. of prod. types	Reduced Set 1: Cap. (bps)	Reduced Set 2: No. of prod. types	Reduced Set 2: Cap. (bps)
Cloud	21078	20	13490	5	3372	1	674
Turbulence	16390	60	31469	24	12588	2	1049
Icing	19304	19	11737	16	9884	4	2471
Wind and Temp.	39995	528	675756	96	122865	48	61432
Surface Conditions	27910	5	4466	1	893	1	893
Convection	21996	1	704	1	704	1	704
Satellite	805241	2	51535	2	51535	2	51535
NEXRAD	26277	1	841	1	841	1	841
Lightning	8234	1	263	1	263	1	263
Total			***790261***		***202945***		***119862***

- **68 kbps without satellite**
- **Wind and Temp may warrant further pruning (could reduce to 38 kbps)**

Graphical Product Capacity

Regional

Product	Size (bytes)	Number of product types	Capacity (bps)	Number of product types	Capacity (bps)
Convection	16576	1	530	1	530
Satellite	355692	2	22764	0	
NEXRAD	32121	1	1028	1	1028
Total			***24322***		***1558***

Comparison with Other Studies

	MFCD		HFCD
Source	**Regional**[1]	**CONUS**	**CONUS**
DO-237[2]	19.6 bps	9.8 kbps	19.6 - 39.2 kbps
LM[2]	194.5 bps	207 kbps	304 - 499 kbps
SAIC[3]	200-900 bps	N/A	248 kbps
LL	220 bps	N/A	N/A
APL	1.3-24.6 kbps	38 - 790 kbps	183 - 1406 kbps

- Notes
  - 1: Region sizes are not necessarily uniform between estimates
  - 2: Estimate shown utilize the DO-237-recommended 3:1 compression
  - 3: Based on LM compression (typically well above 10:1), larger overhead (estimates could not be independently verified)
- Reasons for differences:
  - Product composition (e.g., DO-237 more focused on text, rather than graphical products)
  - Compression in SAIC estimates (based on LM study) greater than typical found in APL assessment

Further Research Areas

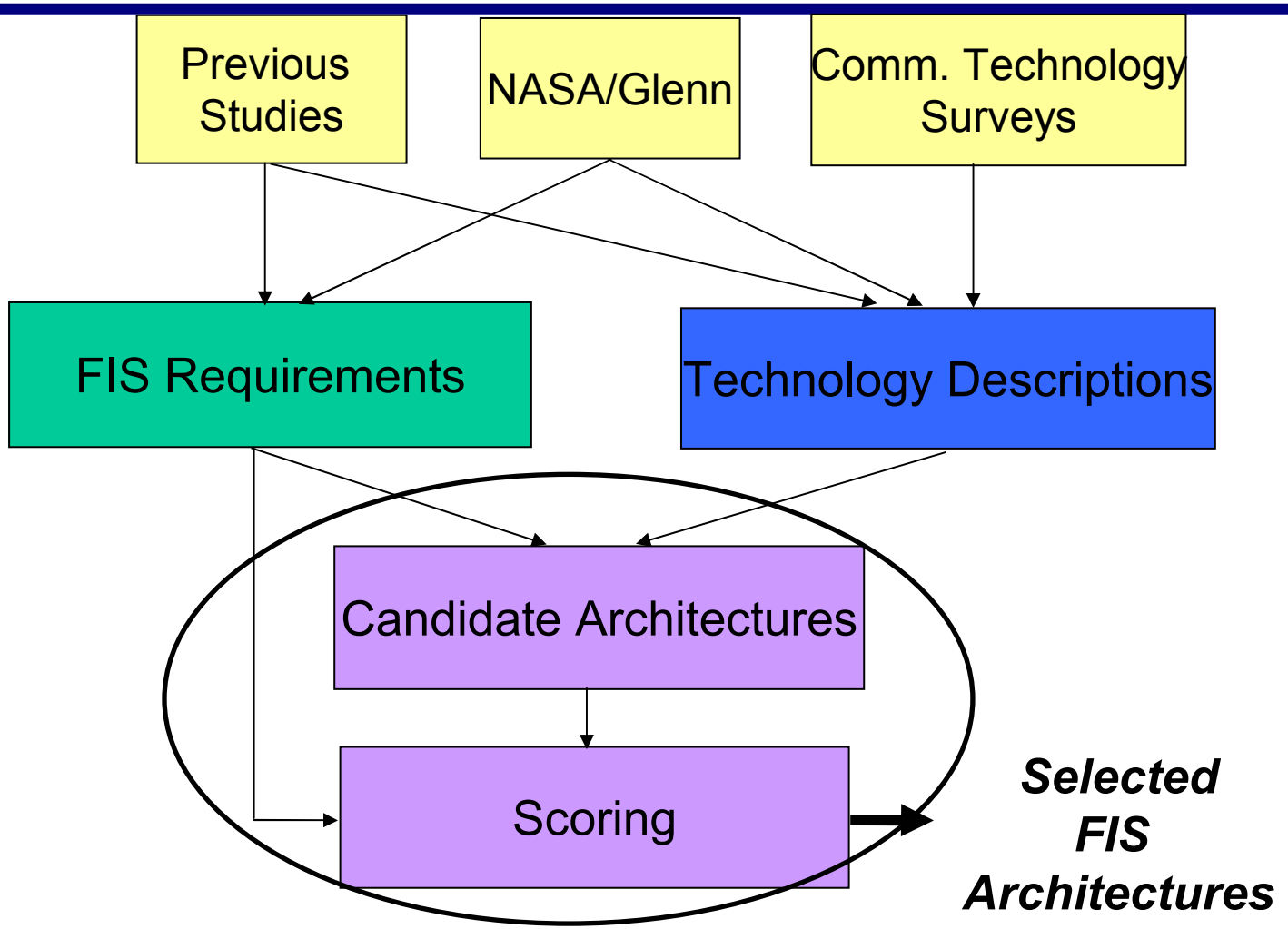
- Product Composition
  - What product types?
  - What flight levels, forecast horizons, etc.?
- Graphical Weather Product Size/Fidelity
  - How many pixels per image?
  - How many bits per pixel?
- Compression
  - What are efficient techniques?
  - Should lossy compression be considered? How to determine what is sufficient quality?
- Product Size Variation
  - How much size variation occurs over time due to compression (non-linear effect)?
  - How should corresponding communications system handle variation?

Requirements Rollup

Scoring Rqmt Area	Summary Requirements
Ground-to-Air Capacity	High-Fidelity, Comprehensive: 183 kbps Multi-Fidelity, Comprehensive: - regional: 1.3 kbps - CONUS: 38 kbps
Platform Constraints	Appropriate for GA/regional aircraft
Coverage	CONUS and Global
Cost	Under $5000 NRE; minimum recurring
Spectrum/Deployment	System operational by 2007 and 2015
Link Availability	99%
Latency	5 minutes

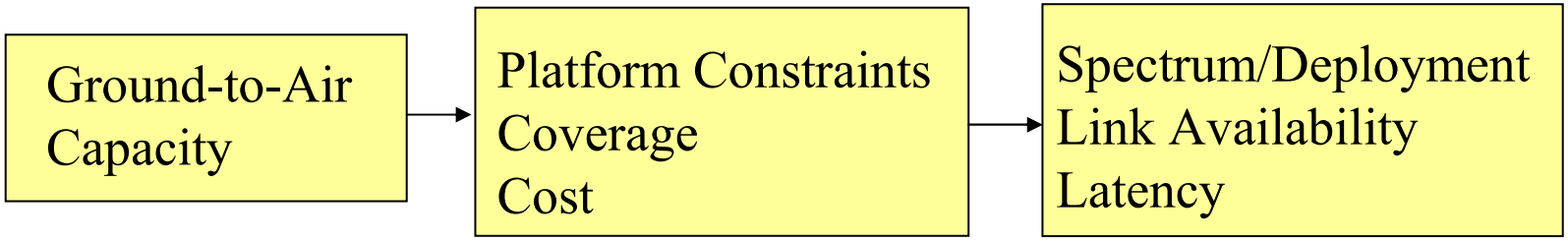
- This set used for architecture analysis and scoring

Architecture Analysis Process



Scoring Methodology

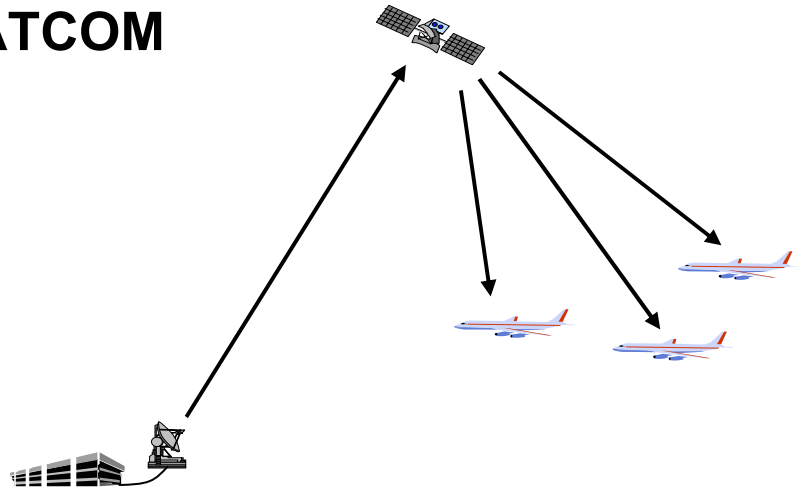
- Scoring conducted through a series of "filters"
- Only viable technologies passed to next scoring filter



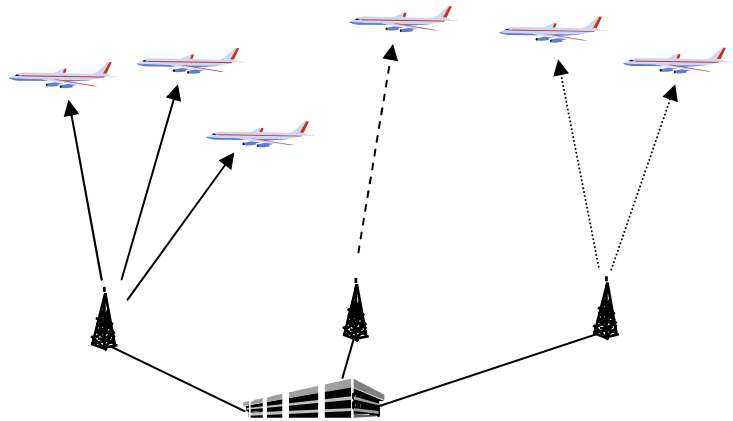
Score	Description
-1	System does not meet requirements
0	Information obtained is currently inadequate to score
1	System can support requirement
2	System can support requirement with substantial margin

Architectures (Broadcast)

SATCOM

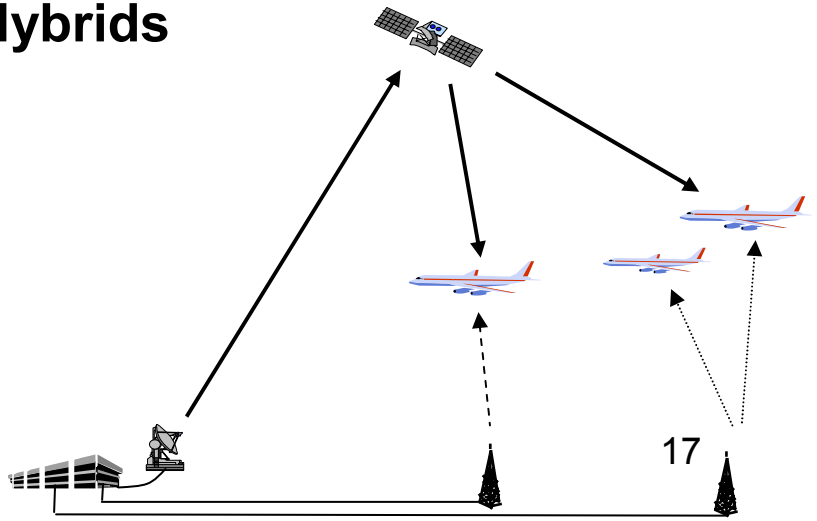


LOS - Broadcast



- Each architecture has benefits and limitations
- Further detailed engineering analysis needed on several options

Hybrids



SATCOM Scores

- Volatility in some sectors of SATCOM industry is an important consideration
- Several open questions on technical system details exist

System	Spectrum/ Deployment	Link Availability	Latency
Iridium	1	0	2
Globalstar	1	0	2
ICO	1	0	2
Ellipso	1	0	2
Inmarsat	2	0	2

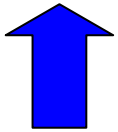
System	HFCD	MFCD	
		regional	CONUS
Iridium	-1	2	-1
Globalstar	-1	2	-1
ICO	2	2	2
Ellipso	-1	2	-1
Teledesic	2	2	2
Inmarsat	2	2	2
Spaceway	2	2	2
eSAT	-1	2	1
UHF	-1	2	1
SHF	2	2	2
S-DARS	0	2	0
Store-and-Forward	-1	0	-1

System	Platform Constraints	Coverage	Cost
Iridium	2	2	2
Globalstar	2	2	2
ICO	1	2	1
Ellipso	1	2	1
Teledesic	-1	2	-1
Inmarsat	2	2	1
Spaceway	-1	2	-1
S-DARS	0	2	0

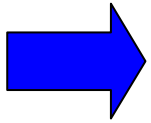
LOS Scores

- LOS systems do not provide viable options for the larger distributions
- Several open questions on technical system details exist

System	Spectrum/ Deployment	Link Availability	Latency
VDL M2	2	2	2
VDL M3	1	0	2
UAT	1	1	2
3G Cellular	1	0	2
4G Cellular	1	0	2
Aircell	2	0	2
Mobitex	2	0	2
ACARS	2	2	2



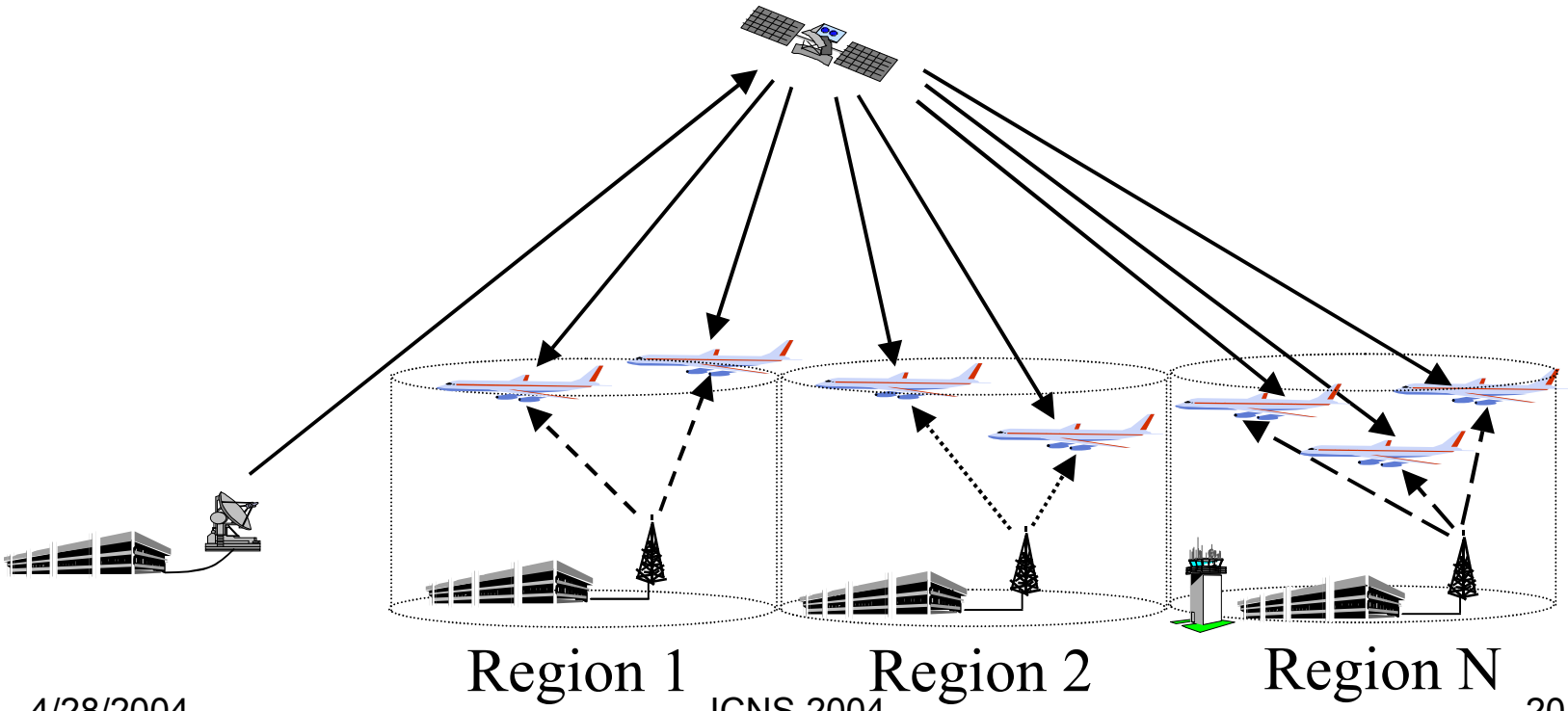
System	HFCD	MFCD	
		regional	CONUS
VDL M2	-1	2	-1
VDL M3	-1	2	-1
VDL M4	-1	-1	-1
802.11	-1	-1	-1
1090 ES	-1	-1	-1
UAT	0	0	0
GATElink	2	2	2
HFDL	-1	1	-1
3G Cellular	0	2	2
4G Cellular	0	2	2
Aircell	-1	2	-1
Magnastar	-1	2	-1
Mobitex	-1	2	-1
ACARS	-1	2	-1
AAN	-1	2	-1



System	Platform Constraints	Coverage	Cost
VDL M2	2	2	1
VDL M3	2	2	1
UAT	2	2	1
GATElink	2	-1	0
HF	2	2	-1
3G Cellular	1	0	0
4G Cellular	1	0	0
Aircell	2	1	1
Magnastar	2	1	-1
Mobitex	1	0	0
ACARS	2	0	2

Hybrid Architectures

- Logical choice is SATCOM for CONUS product delivery and LOS for regional product delivery in an MFCD approach



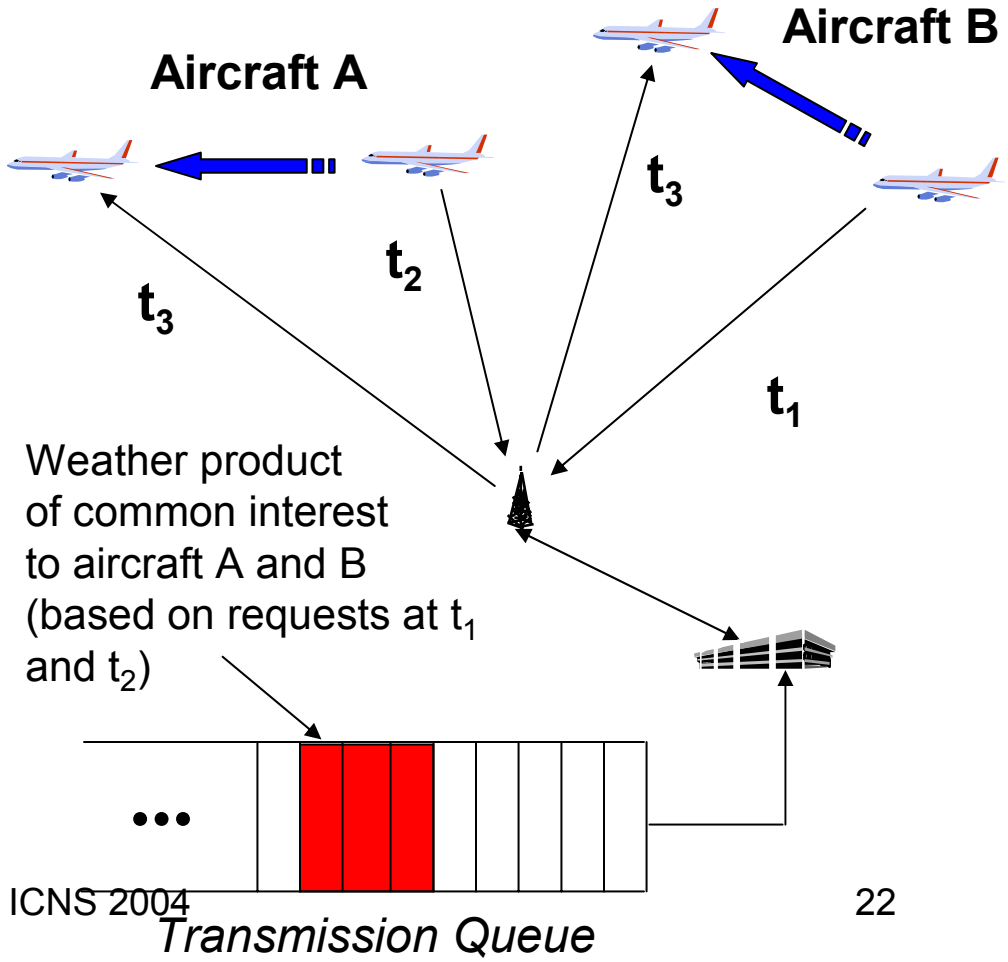
Hybrid Scores

- Based on earlier scoring (partitioned by distribution method) the following emerge:
  - SATCOM: Inmarsat, ICO, S-DARS, eSAT
  - LOS: VDL M2, VDL M3, 1090ES, UAT, DARC, Aircell, ACARS
- Qualitative considerations:
  - Business cases for "piggybacked" requirements
    - No hybrid is likely to meet price point
    - Utilize links that may already be on aircraft
  - VHF transition
  - More detailed technical assessment

Alternative Architectures

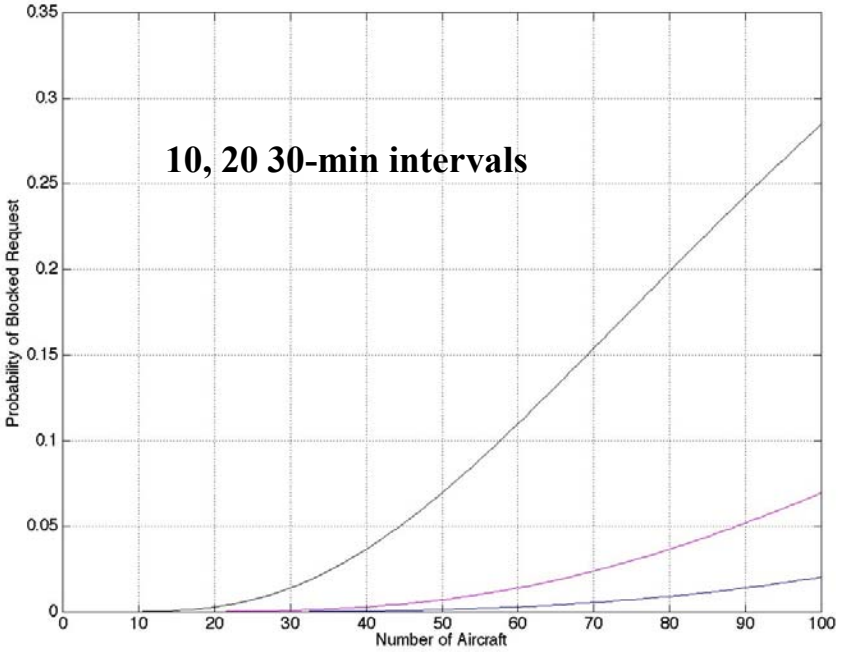
- Broadcast has been studied in current effort
- Other architectures are important to consider for potential improved resource efficiency
  - Request/Reply
  - Adaptive Request/Reply
  - Others

Notional Example



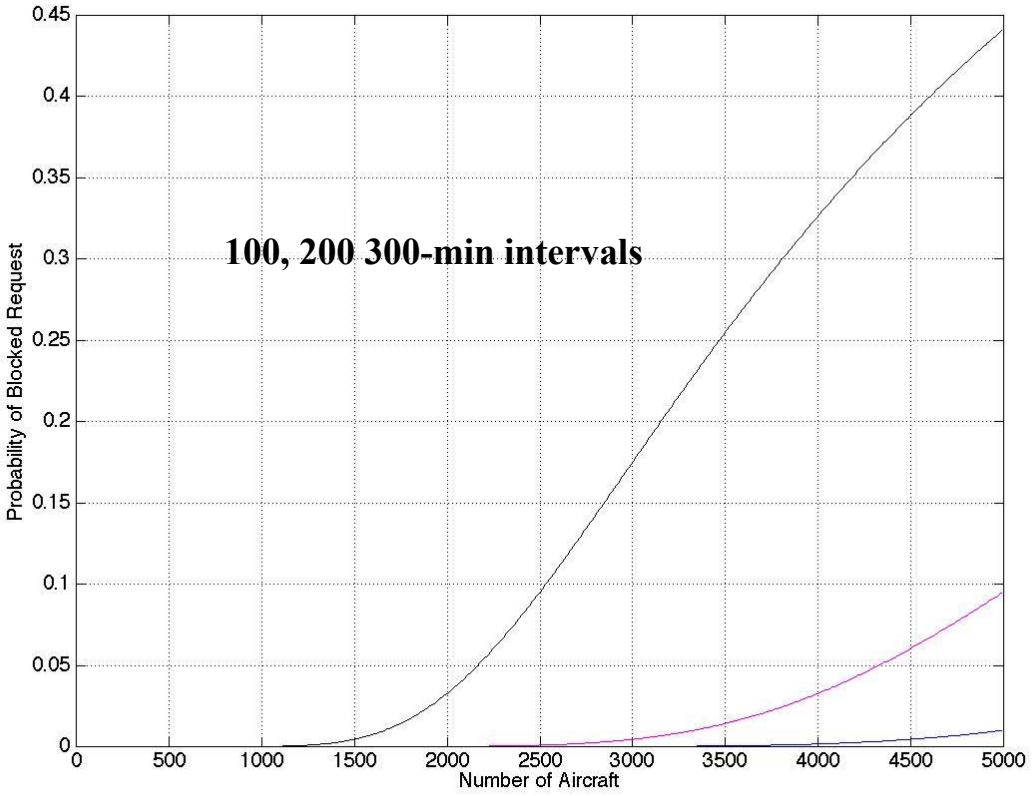
Alt. Architecture Results

- Considered some theoretical cases
  - Trade space of number of aircraft, product request statistics, capacity (and partitioning), delivery time
- Example
  - Broadcast
    - 100 products
    - 30 kbit product size
    - Link of 10 kbps for 300-second latency
    - 150 sec. average wait
  - Request/reply
    - Five 1 kbps links (half broadcast capacity)
    - 30 sec. wait (unless blocked)



Alt. Architecture Results (cont'd)

- Examined a realistic case
  - 160 kbit product (~NEXRAD)
  - 150 products (NEXRAD sites)
  - Broadcast capacity: 80 kbps



Summary

- FIS requirements could warrant further investigation and community discussion
- Architecture task has found candidate systems which could support FIS-B
- Broadcast architecture seems to be efficient mechanism for transfer vs. alternative architectures